CHAPTER 6

Multiplexing

Review Questions

1. FDM, WDM, and TDM.
2. In FDM each signal modulates a different carrier frequency. The modulated carriers are combined to form a new signal that is then sent across the link.
3. A guard band keeps modulated signals from overlapping and interfering with one another.
4. A demultiplexer uses a series of filters to decompose the multiplexed signal into its constituent component signals.
5. Voice channels (12 x 4 KHz) are multiplexed onto a higher bandwidth line to create a group (48 KHz). Up to five groups (5 x 48 KHz) can be multiplexed to create a super group (240 KHz). Ten super groups (10 x 240 KHz) are multiplexed to create a master group (2.52 MHz). Six master groups are multiplexed to create a jumbo group with 16.984 MHz.
6. WDM is conceptually the same as FDM. Both are combining different signals of different frequencies. In WDM the frequencies are very high and the energy source is light signals.
7. In TDM digital signals from n devices are interleaved with one another forming a frame of data.
8. In TDM the demultiplexer at the receiver decomposes each frame by extracting each data unit in turn. As a data unit is removed from the frame it is passed to the appropriate receiving device.
9. If there are *x* lines being multiplexed together and the duration of a data unit is *n* before multiplexing, then after multiplexing the data unit has a duration of *n/x*.
10. DS-0: single digital channel (64 Kbps)
    DS-1: 24 DS-0 channels multiplexed = 1.544 Mbps
    DS-2: 4 DS-1 channels multiplexed = 6.312 Mbps
    DS-3: 7 DS-2 channels multiplexed = 44.376 Mbps
    DS-4: 6 DS-3 channels multiplexed = 274.176 Mbps

11. DS is the name of the service, which is implemented by T-lines. The capacity of the lines precisely matches the data rate of DS-services.
12. In order to use T lines for analog transmission the analog signal needs to be sampled first.
13. The number of slots is the same or greater than the number of input lines.
14. Bit padding is a technique for TDM. The framing bit is used in TDM.
15. Inverse multiplexing splits a data stream from one high speed line onto multiple lower speed lines.

Multiple-Choice Questions

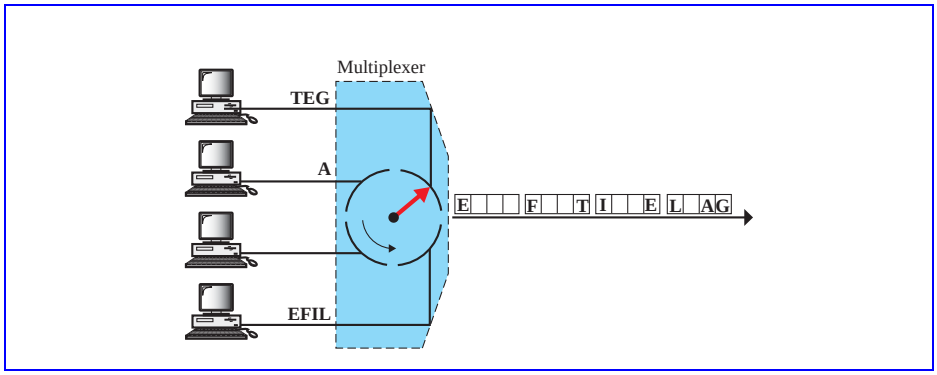
16. d
17. d
18. b
19. a
20. a
21. a
22. a
23. c
24. b
25. a
26. c

Exercises

27. $(4000 \times 5) + (200 \times 4) = 20.8$ KHz
28. $(7900 \text{ Hz} - (200 \times 2)) / 3 = 2.5$ KHz
29. 100 frames/second, each frame contains 5 characters (40 bits) and one extra frame bit, for the total of 41 bits per frame. Bit rate is 100 x 41 = 4100 bps or 4.1 Kbps
30. See Figure 6.1.
31. 125 μs
32. 168 Kbps
33. Nyquist theorem dictates that the sampling rate must be twice the highest frequency; 2×4000 Hz or 8000 Hz.
34. Theoretically, 2,000,000, 000 / 64,000 or 31250 channels. However, we need framing bits for multiplexing. Therefore, the practical number of channels is a little bit less than 31250.
35.

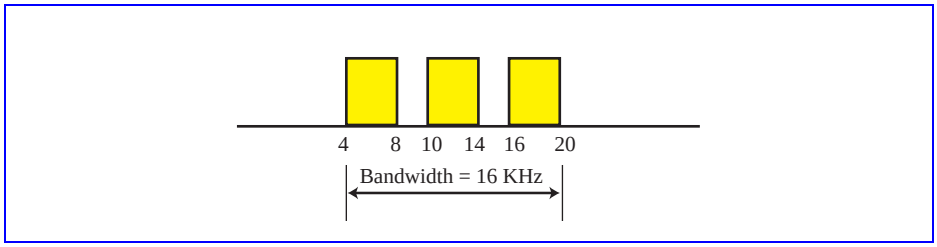
    T1 line $\Rightarrow$ $(1{,}544{,}000 - 24 \times 64000) /24 = 333$ bits /channel $\Rightarrow$ 0.5%
    T2 line $\Rightarrow$ $(6{,}312{,}00 - 96 \times 64000) /96 = 1750$ bits /channel $\Rightarrow$ 2.7%
    T3 line $\Rightarrow$ $(44{,}736{,}000 - 672 \times 64000) /672 = 2571$ bits /channel $\Rightarrow$ 4.0%
    T4 line $\Rightarrow$ $(274{,}176{,}000 - 4032 \times 64000) /4032 = 4000$ bits /channel $\Rightarrow$ 6.2%

Figure 6.1 *Exercise 30*



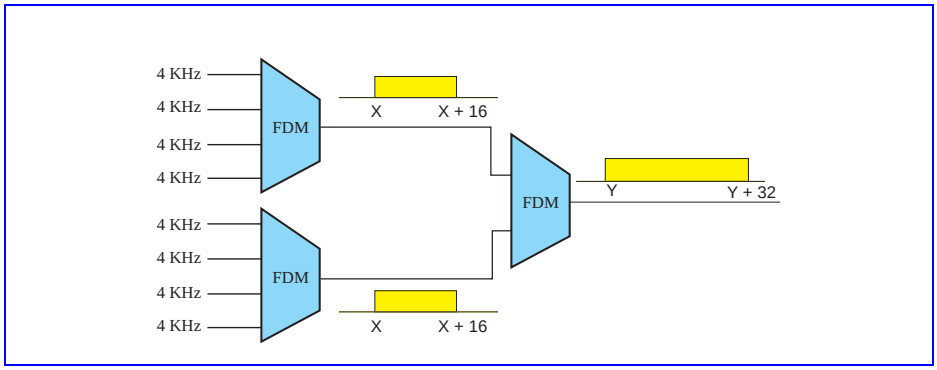
36. Bw = 20KHz – 4KHz = 16 KHz. See Figure 6.2

Figure 6.2 *Exercise 36*



37. See Figure 6.3.

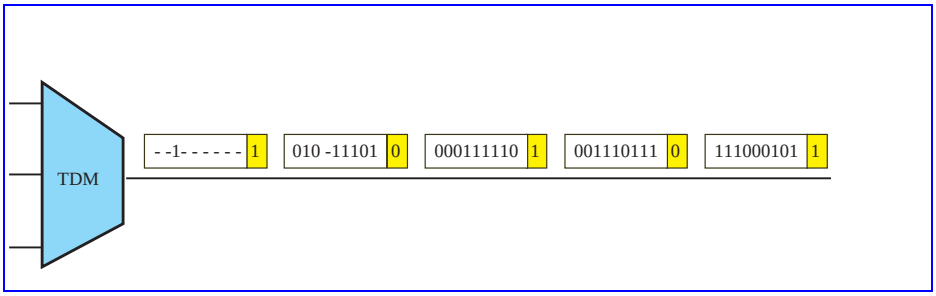
Figure 6.3 *Exercise 37*



38. 14.4 Kbps × 100 = 1.44 Mbps; assuming the overhead is not too big; a T1 line could handle the situation (1.544 Mbps)
39. 2 × 566 Kbps = 1.132 Mbps
40. See Figure 6.4. Each line sends 300 kbps or 100,000 3-bit units per second. Each frame carries one unit from each line, so we need to send 100,000 frames per second. Each frame carries three units, so 300,000 slots per second. The duration of

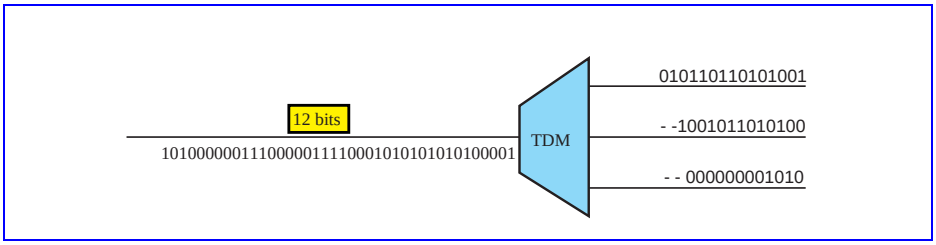
each slot is 1/300,000 seconds. Each frame sends 10 bits, so the bit rate is 1 Mbps. The duration of each bit is 1 μs.

Figure 6.4 *Exercise 40*



41. See Figure 6.5

Figure 6.5 *Exercise 41*



42. 3 Mbps; T1 is not appropriate in this case (1.544 Mbps)
43. 8 Kbps
44. See Figure 6.6. We need 7 T-1 lines.

Figure 6.6 *Exercise 44*